Scientists use world's fastest supercomputer to explore magnetic reconnection

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Los Alamos, New Mexico, October 30, 2009—Although physicists have made considerable progress understanding magnetic reconnection, many important questions are still being debated. Reconnection is a fundamental process in physics, the continuous breaking and rearrangement of magnetic field lines in a plasma. Together with theory and experiments, computer simulations are playing a central role in making new scientific discoveries in reconnection. This is especially true since some of the most outstanding questions require a fundamental description of the associated plasma physics.

According to LANL physicist Bill Daughton of the Plasma Theory and Applications group, understanding the three-dimensional evolution of magnetic reconnection at the most basic level remains an exceptionally challenging problem.

On the Roadrunner machine, researchers at LANL are using VPIC, a particle-in-cell plasma physics code, to perform unprecedented simulations of reconnection relevant to both space and laboratory applications. To model reconnection in large astrophysical plasmas, researchers are employing a technique that allows the plasma and magnetic field to cross the boundaries of the simulation.

The focus is to understand the three-dimensional evolution of thin electrical current layers where magnetic reconnection initially develops. “We know these layers are unstable to tearing modes, which produce magnetic islands as reconnection develops,” said Daughton. “In three-dimensions, multiple tearing instabilities produce rope-like structures that interact in complex and highly dynamic ways. The problem is inherently three-dimensional, and this is the first time it has been studied with first-principles simulations.”

Reconnection physics is also of great interest in laboratory plasmas. “In order to stay grounded in reality, we are performing direct comparisons with the Magnetic Reconnection eXperiment (MRX) at Princeton University,” said Daughton. “Recent experiments at MRX have reported detailed measurements of the electron current layers that form during the reconnection process. Our goal is to understand how plasma instabilities that develop in this layer influence the larger dynamics. We are seeing some exciting similarities and will be working with the experimentalists to understand the implications."

The physics of magnetic reconnection is central to understanding the processes that control the earth's magnetosphere, a kind of "global shield" that protects the earth from deadly cosmic radiation coming from solar flares and the solar wind.

Understanding reconnection physics may lead to better models of the near earth space environment and the potential harmful effects to both space travelers and satellites.

In magnetic confinement fusion, an approach that relies on a magnetic "bottle" to contain nuclear fusion fuel in a plasma reactor, reconnection instabilities can degrade or completely destroy the confinement.

"We are excited by these initial large-scale simulation results," said Daughton.

"Together with theory, laboratory experiments, and satellite observations, we believe these simulations are a powerful new tool that will allow us to resolve some longstanding questions."

In the future, this capability could be useful to scope out new experimental designs before they are built, and to better interpret the large amount of data from NASA satellite missions that are specifically focused on magnetic reconnection in the earth's magnetosphere.

The magnetic reconnection team includes Daughton, Vadim Roytershteyn, Lin Yin, Brian Albright, Kevin Bowers, and Ben Bergen.

About Roadrunner, the world's fastest supercomputer, first to break the petaflop barrier

On Memorial Day, May 26, 2008, the "Roadrunner" supercomputer exceeded a sustained speed of 1 petaflop/s, or 1 million billion calculations per second. "Petaflop/s" is computer jargon—peta signifying the number 1 followed by 15 zeros (sometimes called a quadrillion) and flop/s meaning "floating point operation per second." Shortly after that it was named the world's fastest supercomputer by the TOP500 organization at the SC08 supercomputing conference.

The Roadrunner supercomputer, developed by IBM in partnership with the Laboratory and the National Nuclear Security Administration, will be used to perform advanced physics and predictive simulations in a classified mode to assure the safety, security, and reliability of the U.S. nuclear deterrent. The system will be used by scientists at the NNSA's Los Alamos, Sandia, and Lawrence Livermore national laboratories.

The secret to its record-breaking performance is a unique hybrid design. Each compute node in this cluster consists of two AMD Opteron™ dual-core processors plus four PowerXCell 8i™ processors used as computational accelerators. The accelerators used in Roadrunner are a special IBM-developed variant of the Cell processor used in the Sony PlayStation 3®. The node-attached Cell accelerators are what make Roadrunner different than typical clusters.

In August 2009 Roadrunner continued as the world's fastest with a speed of 1.105 petaflop/s per second, according to the TOP500. The announcement was made at the International Supercomputing Conference SC09 in Hamburg, Germany.